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<b>(21) International Application Number:</b> PCT/SE91/00590 <b>(22) International Filing Date:</b> 9 September 1991 (09.09.91) <b>(30) Priority data:</b> 9002920-8 13 September 1990 (13.09.90) SE <b>(71) Applicant (for all designated States except US):</b> TELEVERKET [SE/SE]; S-123 86 Farsta (SE). <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only) :</b> WICKMAN, Johan [SE/SE]; Televerket Radio, S-205 77 Malmö (SE). HÅKANSSON, Agne [SE/SE]; Gymnasiegatan 11A, S-214 51 Malmö (SE). <b>(74) Agents:</b> HOLMQVIST, Lars, J., H. et al.; Lars Holmqvist Patentbyrå AB, P.O. Box 4289, S-203 14 Malmö 4 (SE).		<b>(81) Designated States:</b> AT (European patent), BE (European patent), CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US.  <b>Published</b> <i>With international search report.</i> <i>In English translation (filed in Swedish).</i>
<b>(54) Title:</b> METHOD OF LOCATION IN A MOBILE RADIO SYSTEM  <b>(57) Abstract</b> <p>The invention relates to a method of location in mobile radio systems, especially the existing mobile radio system GSM. The invention utilizes existing components of the network, such as base stations with associated signaling systems to locate the mobile stations located within the network area. According to the invention each mobile station listens continuously on control channels from surrounding base stations and selects at least three of the base stations and calls these. The base stations each calculate its distance to the mobile station. The calculated distance information and identity information about the mobile station and the selected base stations are transmitted to a location unit determining the location of the mobile station. The distances between the mobile station and the base stations are preferably determined with the circle method.</p> <div data-bbox="860 1134 1445 1785"></div>		

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<sup>+</sup> Any designation of "SU" has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.

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TITLE OF INVENTION: METHOD OF LOCATION IN A MOBILE  
RADIO SYSTEM

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FIELD OF THE INVENTION

The present invention relates to a method of location in mobile radio systems. The invention relies especially on an existing network for mobile telephony, CEPT GSM (Groupe  
15 Speciale Mobile). The specifications of GSM relate to a Pan-European network for mobile telephony and data communication functions. The invention utilizes existing system components in a network, base stations, mobile stations as well as the signaling system in a new way to provide a new function, the  
20 location. The invention is based on absolute measurement of distance between the unknown position, the position of the mobile station, and three fixed reference points, base stations.

25 THE STATE OF THE ART

Location has been a well-established concept for a long time. Various mathematical methods are known, for instance the circle and hyperbola methods, which are used for location. This has also occurred previously in radio systems, see  
30 for instance European patent application 0 320 913.

However, the previously proposed methods involve modifications of the existing specifications of the radio systems. The present invention in contrast utilizes only a sequence of already existing functions, especially in the GSM system.  
35 According to the present invention, for instance no synchronization of the base stations is required, which is necessary with the previously known technique.

SUMMARY OF THE INVENTION

40 Thus, the present invention provides a method of loca-

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tion in mobile radio systems comprising mobile stations and base stations. According to the invention, every mobile station listens continuously on channels from surrounding base stations of which at least three are selected. The mobile  
5 station calls a selected base station which calculate their distances to the mobile station. The calculated distance information and identity information of the mobile station and the selected base stations are transmitted to a location unit determining the location of the mobile unit.  
10 Further embodiments of the invention are set forth in the accompanying claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described with reference to  
15 the accompanying drawings in which  
figure 1 is a diagram depicting the mathematical method used,  
figure 2 illustrates schematically the structure of the mobile radio system,  
20 figure 3A is a flow chart of the method according to the invention,  
figure 3B is a continuation of the flow chart of figure 3A according a first embodiment of the invention,  
figure 4 is a continuation of the flow chart of figure  
25 3A in accordance with a second embodiment of the invention, and  
figure 5 is a flow chart for establishing a list of the base stations and forms part of the present invention.

#### 30 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Before the invention is described in detail it is convenient to define certain terms common in this field. Positioning means that a mobile object has the ability of determining its own position, with or without participation  
35 by the environment. Location means that the environment has the ability of determining the position of the mobile object, with or without participation by the object observed. Navigation means that positioning, location is used as a tool for moving from a start point to an end point. The present inven-  
40 tion primarily relates to location, that is the environment's

control of the position of the mobile objects, in this case mobile stations in a mobile telephone network. The present invention also falls within the group of systems wherein angles and/or distances are measured relative to fixed  
5 points. In such systems various geometrical methods are used. One such method is the so called circle method.

In figure 1 the geometrical conditions of the circle method are illustrated. It is based on measurement of three independent distances,  $d_1, d_2, d_3$ . With three given reference  
10 points  $p_1, p_2, p_3$  in a plane it is possible to establish the coordinates of any other point in the same plane using the distances between the reference points and the point in question.

If the reference points have the coordinates  $p_n = (a_n, b_n)$ ,  $n = 1, 2, 3$  the unknown point  $(x_0, y_0)$  is obtained from  
15 the following equation system.

$$\begin{cases} (x_0 - a_1)^2 + (y_0 - b_1)^2 = d_1^2 \\ (x_0 - a_2)^2 + (y_0 - b_2)^2 = d_2^2 \\ (x_0 - a_3)^2 + (y_0 - b_3)^2 = d_3^2 \end{cases}$$

20 Also other mathematical methods may be used with the present invention, for instance the hyperbola method.

A description of the GSM system may be obtained from GSM Recommendations 03, 04 and 05. Below is only a brief summary of the units used in the present invention. CEPT GSM (Groupe  
25 Speciale Mobile) was established in 1982 to formulate specifications for the Pan-European mobile radio system.

The functional architecture is shown in figure 2. The system comprises a base station system BSS with a base station controller BSC and base transceiver stations BTS. The  
30 system also comprises mobile stations MS, a mobile services switching centre MSC with a home location register HLR and a visitor location register VLR.

Two interfaces are mandatory at present, namely the radio interface and the interface between the mobile  
35 switching centre and the base station system. The radio interface is defined according to the layered model and the physical layer comprises a time division multiple access (TDMA) structure having eight time slots per radio carrier.

The TDMA structure is used by channels, logical channels, in higher layers. The logical channels are divided into traffic channels and control channels.

When the mobile station, most often a vehicle, is moving it happens that it enters a new base station area. The mobile station must detect this change of area to provide the home location register with its correct staying area. This means that the mobile station continuously has to scan all the broadcast control channels BCCH of the base stations. It measures the received signal strengths and ranges the strongest stations at the moment in a table. This function is very useful since the mobile stations when locating need to know which three base stations are the best to use.

The GSM system contains a function called adaptive frame alignment AFA. Eight time slots forms a TDMA frame. The TDMA frames of all the frequency channels should be aligned with each other. In the base station the TDMA frame is delayed in the up link with a fixed period of three time slots from the start of the TDMA frame on the down link. In the mobile station the delay in the propagation of the signal is adjusted for. The delay is called timing advance TA. It is the process of adjusting for this delay which is called adaptive frame alignment AFA.

The timing advance TA is measured by a base station each time it detects a transmission on the random access channel RACH. The timing advance TA is defined as the delay of the RACH signal relative to an expected signal from a mobile station on the distance zero. The measured value is rounded to the closest bit period and is signaled to the mobile station. The value of the timing advance TA may be interpreted as a measure of the distance to the base station. The uncertainty is calculated to be approximately 277 metres.

According to the present invention the AFA function is used for measurement of distance for location of mobile units in a mobile telephone system. The method benefits from the fact that the mobiles continuously listen to the control channels of the surrounding base stations and hold the results in a table arranged according to the signal strength. There is no need to synchronize the base stations in this method. The method is described with reference to the flow

chart of figures 3A and 3B. The method is initiated by a location request. How this request is initiated does not form part of the present invention. In the first condition box it is determined if the control channels BCCH are known for the  
5 base stations in the public land mobile network PLMN. If not, these are determined according to the flow chart of figure 5 described below. Thereafter the mobile station measures the signal strengths on the control channels BCCH, selects the three best and stores their frequencies and identities. If  
10 the cell is barred location is permitted only if it is an emergency location, which, thus, is placed in the same category as emergency calls. In GSM it is permitted to make emergency calls via a barred cell.

The flow chart is continued in figure 3B wherein the  
15 mobile unit transmits access bursts AB to the three selected base stations BTS number N on the random access channel RACH. The base station detects the access burst, calculates the timing advance and signals to the mobile station. The mobile station receives three TA values on an access grant channel  
20 AGCH and transmits these together with the respective base station identity codes BSIC and its own identity to a location centre or a location unit. The accuracy of this method is calculated to be 560 metres.

Instead of letting the mobile station receive the timing  
25 advance values, it is possible to let it transmit a location request to the base stations in accordance with an alternative embodiment of the present invention. On receiving such a request the base stations instead transmit the timing advance values with the mobile station identities in question to the  
30 location unit. Since this method uses the TA values before they are rounded and transmitted to the mobile station (in the previous method the received TA values are rounded to the closest bit period) the accuracy is better than 280 metres. However, this approach requires the creation of a new command  
35 in the GSM system, that is the location request. The alternative embodiment differs in the second half of the flow chart in figures 3A, 3B, the flow chart of figure 4 replacing that of figure 3B.

Here, the mobile receives a specially intended control  
40 channel, stand-alone dedicated control channel SDCCH, from

the base stations and transmits the location request on this channel. Thereafter the base station is disconnected and the mobile unit receives an unnumbered acknowledgement UA as in the previous embodiment.

5 In figure 5 is shown how the mobile unit establishes a list of the control channels BCCH from all the base stations in the network PLMN. The list is arranged according to the signal strengths of the carriers.

10 It is possible to improve the accuracy of the methods above by using more than three base stations. Another way is combining the location methods with each other or with some other method, for instance the hyperbola method.

There are many possible applications of the method according to the invention. Examples that may be mentioned  
15 are services in emergency situations and traffic routing. In emergency situations the delay between a traffic accident and the arrival of the help can be decreased owing to mobile telephones existing in the vehicles. Already today nearly 100% of all traffic accidents in Sweden are reported by means  
20 of mobile telephones. However, the situation may be improved further by automatic location of the mobile telephones in accordance with the present invention.

There are many activities that can benefit from traffic routing using automatic location, for instance courier services, package delivery, forwarding, mobility service and  
25 taxi etc. A location service provides a quick selection of the closest vehicle. Of course this means quicker reaction to the customers' desires and a more efficient use of vehicles and drivers. The efficient use of the vehicles also means decreased environmental pollution. The location service makes  
30 it possible for the traffic routing to trace the vehicles in real time on a map on a computer screen.

It will not mean any problems for the network operators of the GSM system to charge for the location service. The  
35 network operator has control over the short message to the location unit. The message is necessary for the location system to work and the operator could charge a fee for this message. It is also possible to have a subscription fee for the information about the coordinates of the base stations.  
40 The network operator can use a part of the control channel



BCCH to notify the traffic within a cell where an accident has occurred. It is possible to have a subscription fee for this information. Furthermore, the network operator offering a location service has a better competitive position.

## CLAIMS

1. Method of location in mobile radio system comprising mobile stations and base stations, **characterized** in that each mobile station continuously listens on control channels  
5 from surrounding base stations,

at least three base stations are selected by the mobile station,

the mobile station calls the selected base stations,  
each of the selected base stations calculates its dis-  
10 tance to the mobile station,

the calculated distance information and identity information about the mobile station and the selected base stations are transmitted to a location unit, and

the location of the mobile unit is determined in the  
15 location unit.

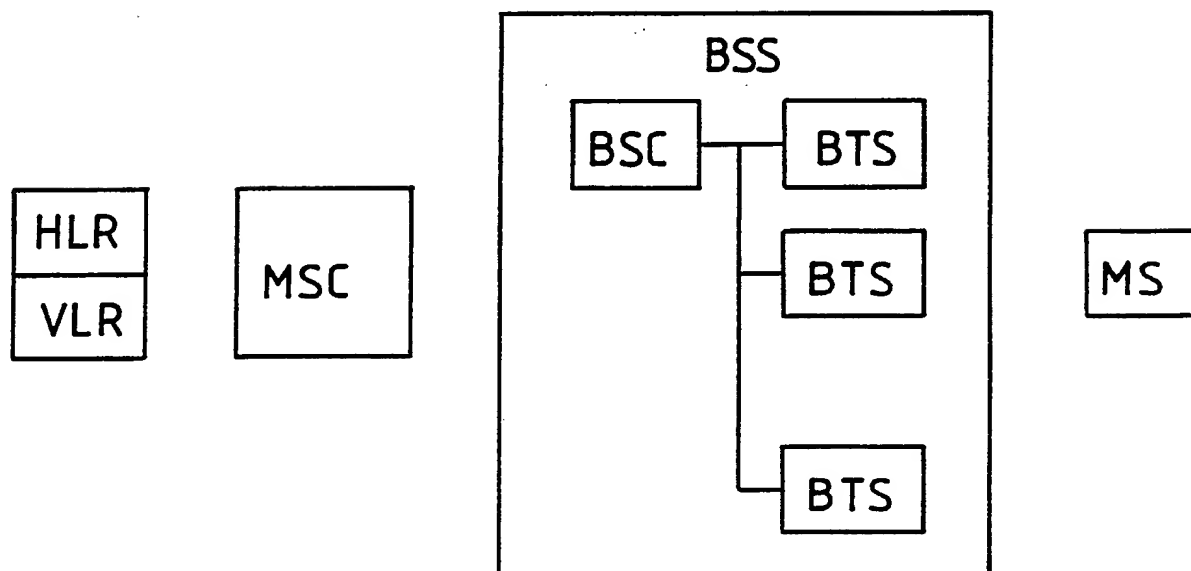
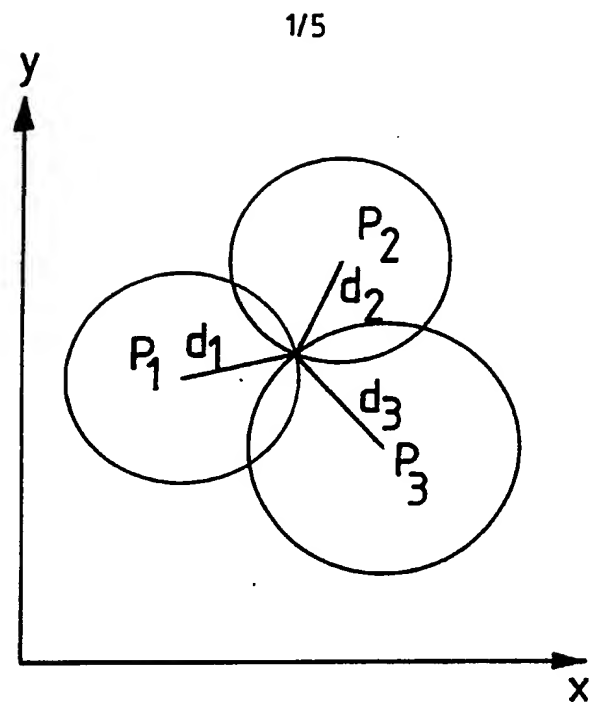
2. Method according to claim 1, **characterized** in that the mobile station calls the selected base stations with an access signal, the base stations transmits the calculated distances to the mobile unit, and the mobile station trans-  
20 mits the information to the location unit.

3. Method according to claim 1, **characterized** in that the mobile station calls the selected base stations using a location requesting signal, and the base station transmits the information to the location unit.

25 4. Method according to anyone of the preceding claims, characterized in that the distances between the mobile station and the respective base station are calculated using the TA value measured by the base station.

5. Method according to claim 4, **characterized** in that  
30 the location of the mobile station is calculated using the circle method.

6. Method according to anyone of the preceding claims, **characterized** in that the base stations having the strongest signal strengths are selected.



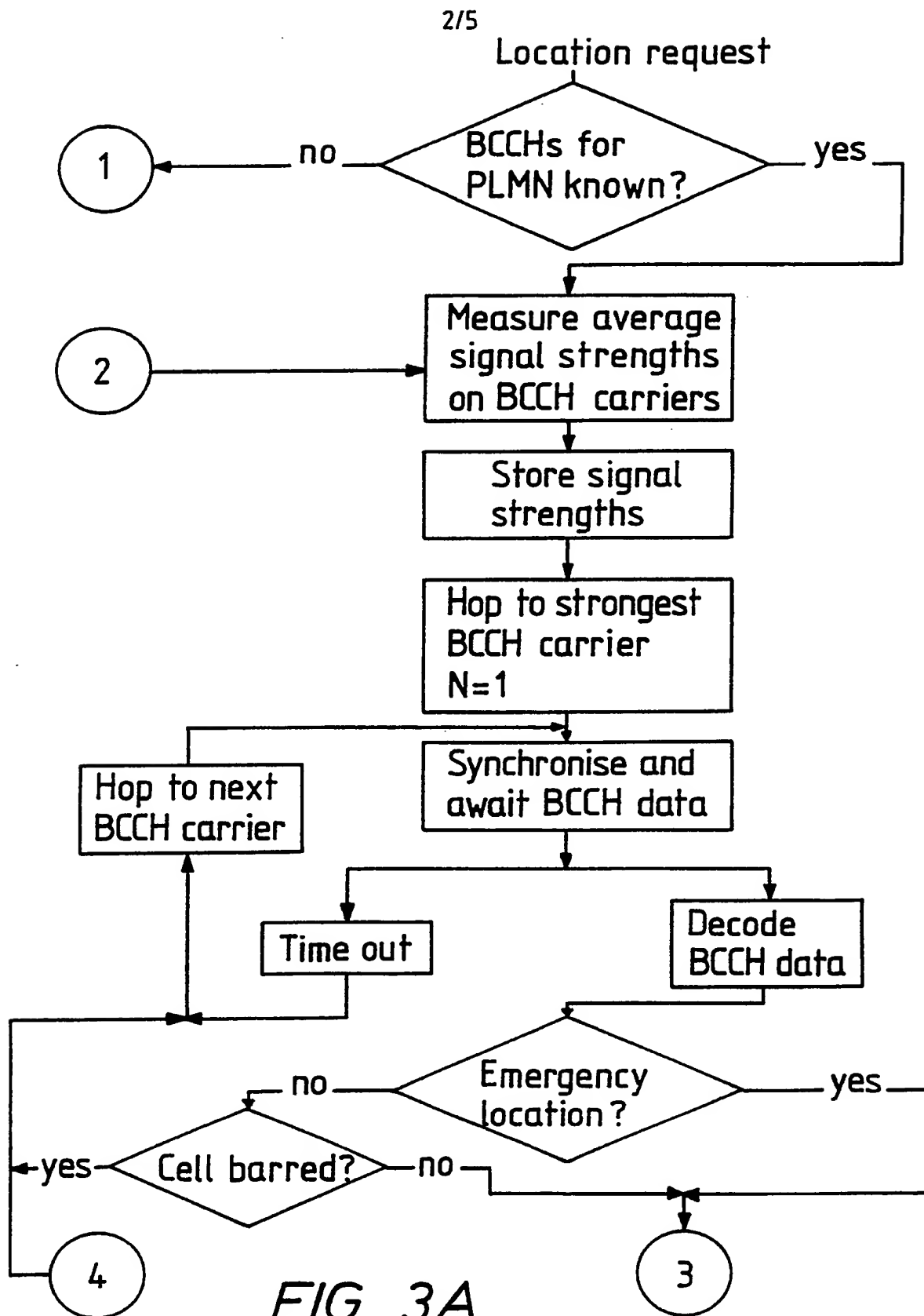


FIG. 3A

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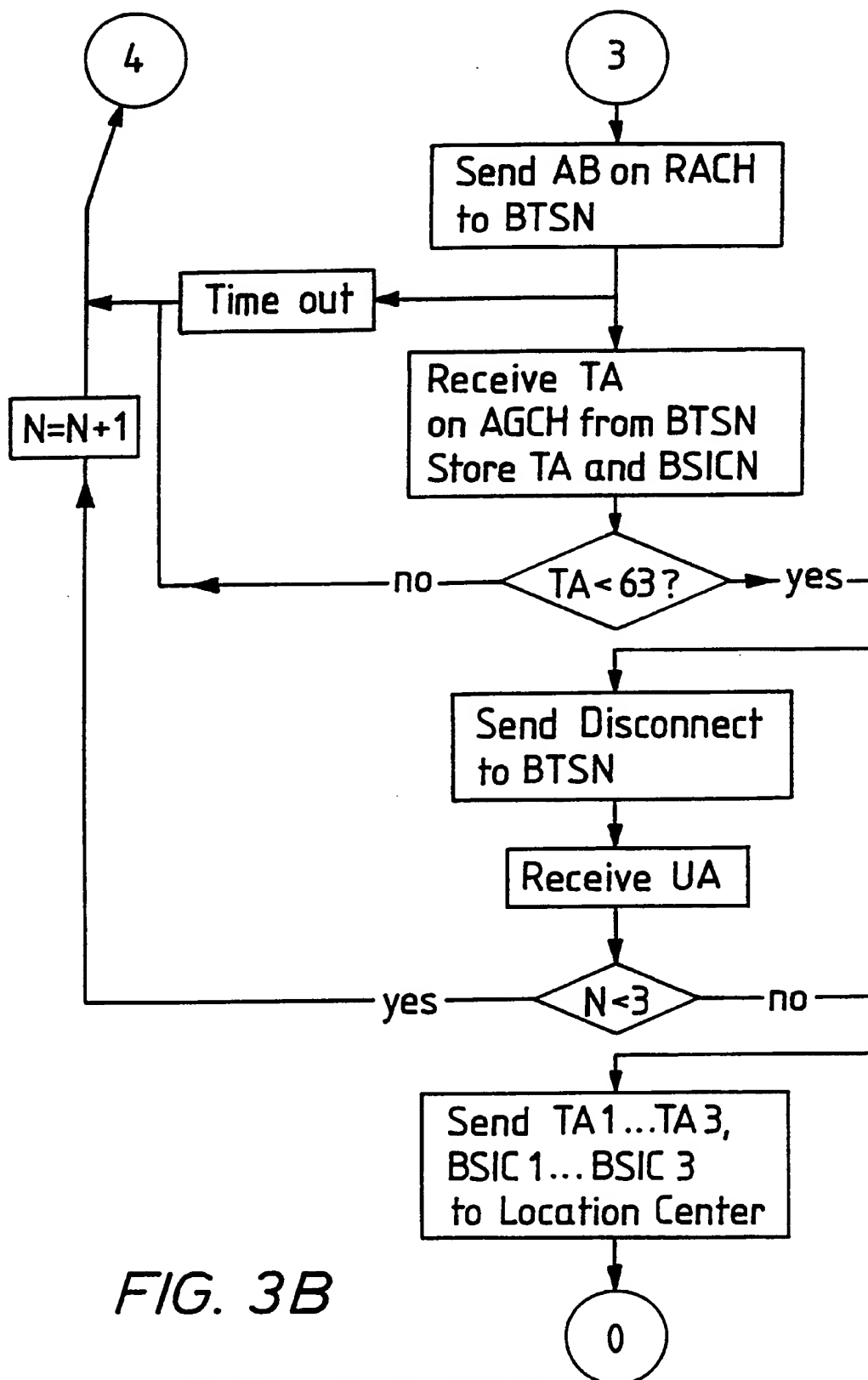


FIG. 3B

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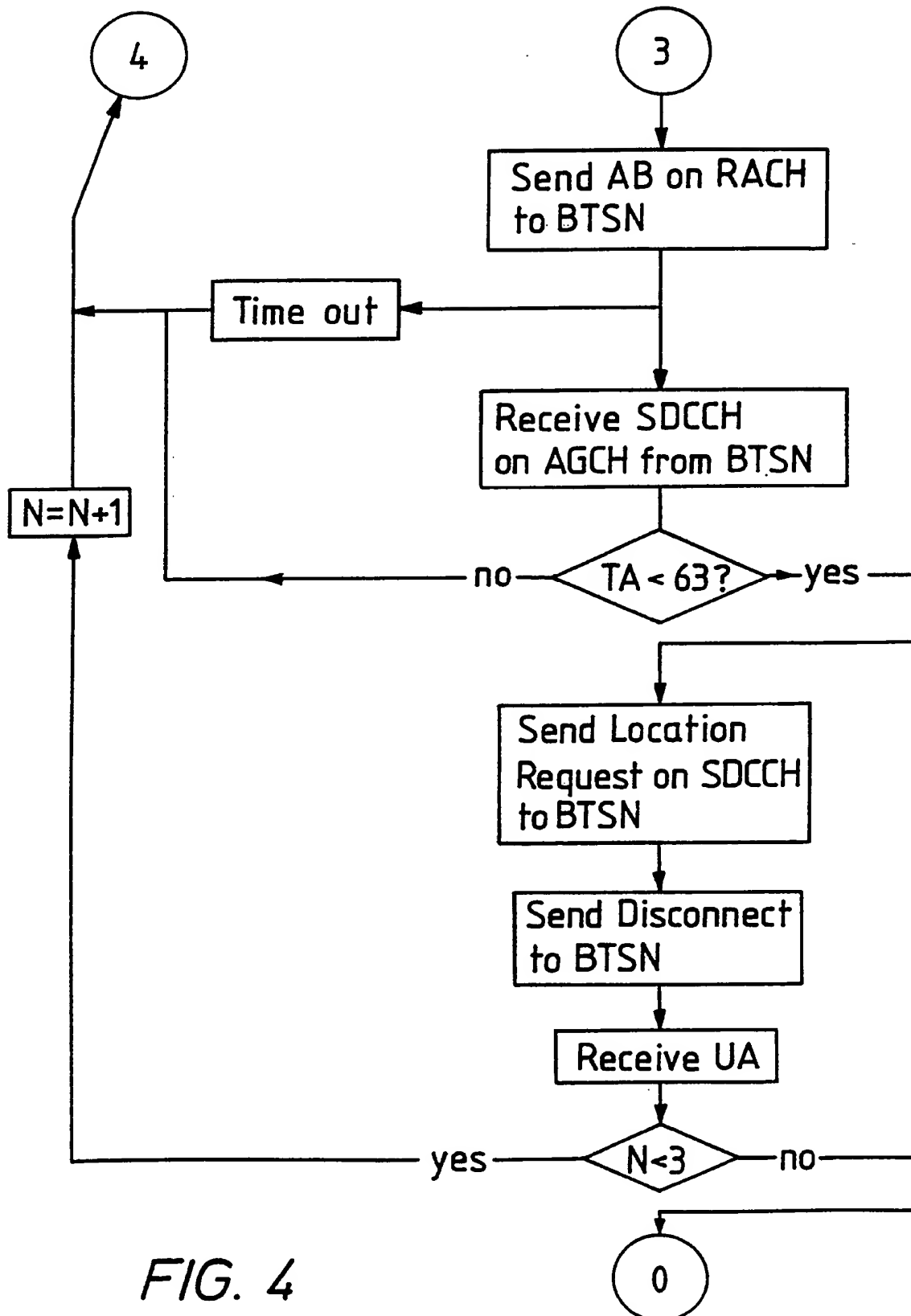


FIG. 4

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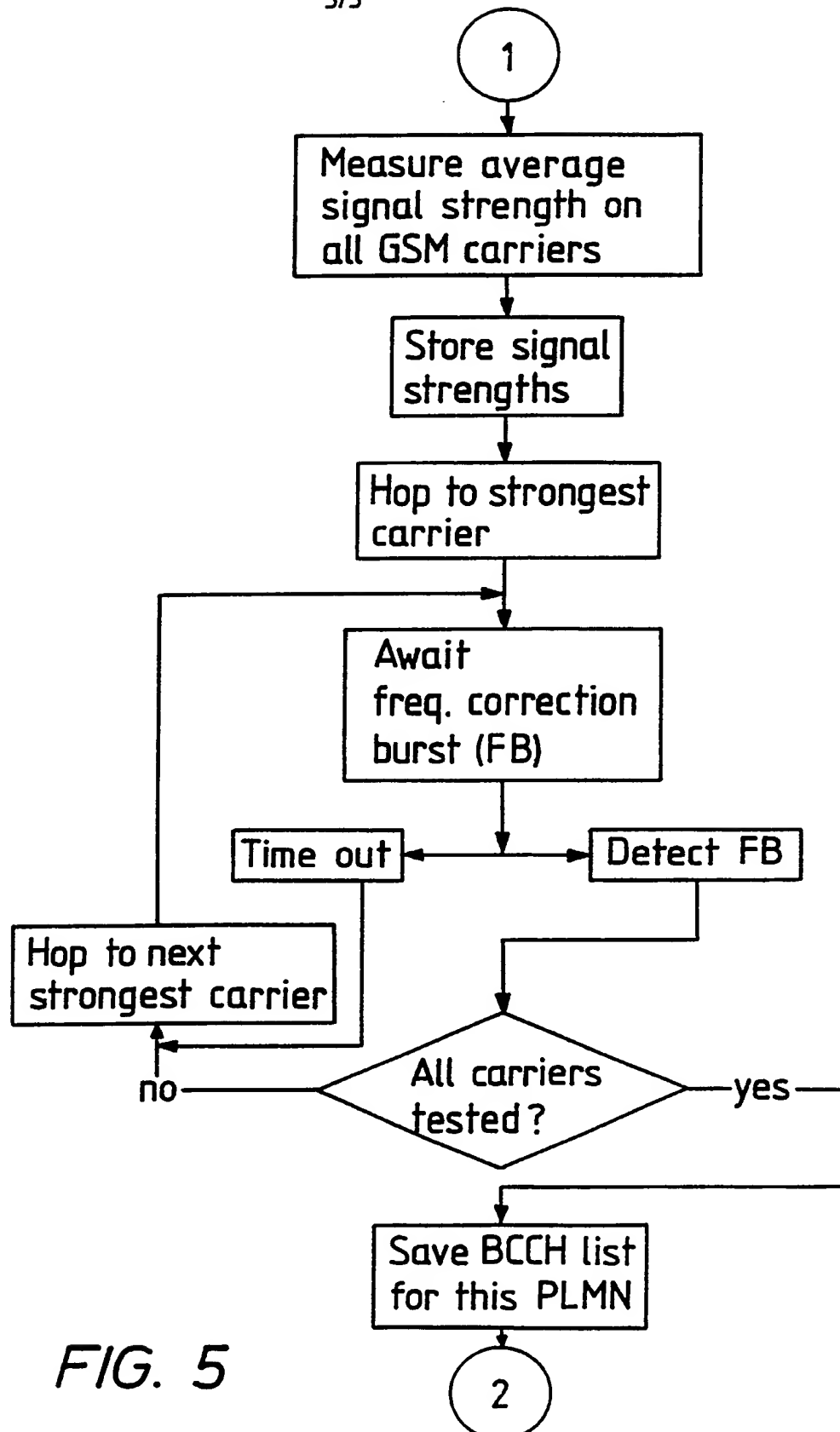


FIG. 5

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# INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 91/00590

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC5: H 04 Q 7/04, G 01 S 5/14		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
IPC5	H 04 B; H 04 Q; G 01 S	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in Fields Searched <sup>8</sup>		
SE,DK,FI,NO classes as above		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>*</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	US, A, 4740792 (W.E. SAGEY ET AL) 26 April 1988, see column 2, line 59 - column 3, line 27 --	1-6
A	EP, A2, 0210396 (ANT NACHRICHTENTECHNIK GMBH) 4 February 1987, see column 1, line 27 - line 34 --	1-6
A	EP, A2, 0341738 (SIEMENS AKTIENGESELLSCHAFT) 15 November 1989, see column 2, line 2 - line 28 --	1-6
A	US, A, 4670905 (J.L. SANDVOS ET AL) 2 June 1987, see the whole document --	1
<p><sup>*</sup> Special categories of cited documents:<sup>10</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
27th November 1991	1991 -12- 06	
International Searching Authority	Signature of Authorized Officer	
SWEDISH PATENT OFFICE	Lars Henriksson LARS HENRIKSSON	



III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	EP, A1, 0072984 (LICENTIA PATENT-VERWALTUNGS-GMBH) 2 March 1983, see the whole document -- -----	1

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.PCT/SE 91/00590**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the Swedish Patent Office EDP file on 31/10/91. The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4740792	88-04-26	EP-A- 0279834 WO-A- 88/01750	88-08-31 88-03-10
EP-A2- 0210396	87-02-04	NONE	
EP-A2- 0341738	89-11-15	DE-A- 3816377	89-11-23
US-A- 4670905	87-06-02	CA-A- 1259660 EP-A- 0247192 WO-A- 87/03438	89-09-19 87-12-02 87-06-04
EP-A1- 0072984	83-03-02	DE-A-C- 3133120	83-03-03